

electron microscopes or astronomical telescopes having large aberrations, for improvement of the resolution. In accordance with this phase restoration method, a phase distribution of an image is detected on the basis of image intensity distributions at plural positions such as image plane, pupil plane, and defocus position, for example. From the detected phase distribution, a wavefront aberration of an optical system is calculated.

The paragraph beginning at line 3 of page 5 has been amended as follows:

For these reasons, when a wavefront aberration of a projection lens is to be detected in accordance with the phase restoration method while using an illumination optical system for a practical exposure process as it is, there is a problem with respect to the precision.

The paragraph beginning at line 18 of page 14 has been amended as follows:

The phase restoration method has been used in the field of electron microscopes or astronomical telescopes having large aberrations, for improvement of the resolution. In accordance with this phase restoration method, a phase distribution of an image is detected on the basis of image intensity distributions at plural positions such as image plane, pupil plane, and defocus position, for example. From the detected phase distribution, a wavefront aberration of an optical system (projection lens) is calculated.

The paragraph beginning at line 3 of page 17 has been amended as follows:

Generally, the value σ in regard to the illumination condition for wafer exposure to print a pattern on the wafer is in a range of about 0.3 to 0.8. Thus, the zoom

optical system may be one covering such range. In the phase restoration method, on the other hand, a reticle must be illuminated in an approximately coherent state wherein σ is not greater than 0.2, preferably not greater than 0.1. For most convenient illumination with σ of 0.2 or less, the aperture 22 shown in Figure 2 may be narrowed to satisfy $\sigma \leq 0.2$. In that occasion, since at the illumination state adjusting unit 20 the light has an expansion as of about $\sigma = 0.3$, an eclipse may occur at the stop 22 portion and, as a result, the light quantity may decrease. Particularly, the light quantity may reduce if σ is not greater than 0.1. Thus, with the phase restoration method wherein the light intensity is to be measured, it may adversely influence the wavefront aberration calculation precision. While a zoom optical system that can cover a range of σ from 0.1 to 0.2 may be used, enlargement of the zoom ration causes an increase in size and weight of the illumination state adjusting unit 20. Further it becomes difficult to suppress non-uniformness of illuminance for all zoom lenses.

The paragraph beginning at line 1 of page 18 has been amended as follows:

In this embodiment, in consideration of the above, as shown in Figure 5, for execution of the projection lens on the basis of the phase restoration method, the illumination state adjusting unit inside the illumination optical system 13 is replaced by the illumination state adjusting unit 24 for the phase restoration method while, on the other hand, the stop is replaced by the stop 25 to change σ to be not greater than 0.2. More specifically, for the exposure process, a zoom optical system with which σ can change from about 0.3 to about 0.8 is used in the illumination state adjusting unit 20. For execution of the phase restoration method, the illumination state adjusting unit 24 for phase restoration method which σ becomes not greater than 0.2 is used. In this manner, in both of the exposure process and phase restoration process, the reticle can be illuminated with best

25
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modes, respectively. As a result of this, the wavefront of the projection lens 1 can be measured very precisely.

The paragraph beginning at line 27 of page 18 has been amended as follows:

26

In this embodiment, as shown in Figure 6, for execution of wavefront aberration measurement based on the phase restoration method, a demountable mirror 27 being movable out of the light path is inserted between a stop 22 and a lens unit 23. A second light source 26 emits light of the same wavelength as the exposure wavelength, so that, through the mirror 27 and the lens 23, a pattern on a reticle 2 is illuminated in coherent state or approximately coherent state. This differs from the first embodiment of Figure 2.

The paragraph beginning at line 2 of page 20 has been amended as follows:

27

In this embodiment, as shown in Figure 7, a second optical system 14 is provided, in addition to the exposure illumination system 13. For detection of a wavefront aberration of the projection lens 1 on the basis of phase restoration method, the second optical system 14 is used to illuminate a pattern on the reticle 2. Also, for an exposure process, the second optical system 14 as well as the mirror 15 move in a direction of an arrow in Figure 7 so as not to interfere with the exposure light. Namely, they are demountable out of the light path. Further, the illumination condition of the second illumination optical system 14 satisfies coherent illumination ($\sigma = 0$) or approximately coherent illumination ($\sigma \leq 0.2$). Thus, the wavefront aberration of the projection lens 1 can be measured, under an idealistic condition for the phase restoration method.

The paragraph beginning at line 1 of page 21 has been amended as follows:

98
Figure 8 is a schematic view of a main portion of a projection exposure apparatus according to a fifth embodiment of the present invention. In Figure 8, elements corresponding to those of Figure 1 are denoted by like numerals.

The paragraph beginning at line 5 of page 22 has been amended as follows:

99
The phase restoration method using the above-described alignment optical system will now be explained. For the alignment measurement process, the alignment mark is illuminated usually with a condition of $0.2 \leq \sigma \leq 1.0$. To this end, in the alignment optical system shown in Figure 8, an interchangeable stop 32 is disposed between the illumination system relay optical system 33 and the beam splitter 29, such that the σ value can be changed between the alignment process and for execution of wavefront aberration measurement based on the phase restoration method. More specifically, for execution of the wavefront aberration measurement based on phase restoration, the stop is changed to provide $\sigma \leq 0.2$, to illuminate a pattern on the reticle. The intensity distribution of an image thereof is then measured by using a light intensity measuring system 8, by which the wavefront aberration of the projection lens 1 can be calculated. Namely, as shown in Figure 8, the interchangeable stop 32 is provided inside the alignment optical system, so that the stop is interchanged between alignment measurement and wavefront measurement based on phase restoration, thereby to assure best illumination states for them. With this structure, without use of any additional optical system, the phase restoration method can be executed very precisely, and the wavefront aberration of the projection lens 1 can be calculated conveniently and very precisely.